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The brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae) in Malta

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Halyomorpha halys, commonly known as the brown marmorated stink bug, has been recorded for the first time from the Maltese Islands. The record is currently based on the capture of a single specimen. Information is provided on the distribution range of this polyphagous species which was accidentally introduced into Europe (Switzerland) in 2007 and since then has invaded many European countries. Morphological details are also included to aid in the discrimination of this species from similar species occurring in the Mediterranean region. Notes are provided on the feeding strategies used by this insect and the type of damage incurred on agricultural commodities, which are often rendered unsaleable.

Introduction

Halyomorpha halys (Stål), commonly known as the brown marmorated stink bug (BMSB), is a phytophagous pentatomid bug indigenous to China, Japan, Korea and Taiwan (Lee *et al.*, 2013). It is a polyphagous species known to feed on more than 300 different host plants and is frequently found on both herbaceous crops and fruit trees. Currently, this bug is considered as an important pest of peas, soy, corn, tomatoes, pepper, aubergine and several fruits such as apple, peach and cherry (Nielsen & Hamilton, 2009a,b; Leskey *et al.*, 2012; Kuhar *et al.*, 2012). Hoebeke & Carter (2003) provided a detailed description of the morphology of this bug. Herein, the authors provide some morphological features which can be useful in helping to identify this species in the field.

Field recognition of *H. halys*

Adults (Fig. 1) vary in length from 12 to 17 mm (males are generally somewhat shorter than females) and have different shades of brownish to greyish coloration. The body shape is similar to that of a shield. The species can be readily distinguished from other native shield bugs occurring in the Mediterranean Basin due to the presence of two whitish bands on the antennae and the presence of alternate brown and white bands on the exposed lateral margins of the abdomen. The eggs are elliptical and whitish, and are often deposited on the underside of leaves in clusters of 20–30 (often 28). Five larval stages are recognized in this species; they vary from 2.4 mm long (the first larval stage) up to 12 mm long in the final larval stage.

Type of damage

Generally, phytophagous stink bugs feed by inserting their needle-like mouthparts into plant stems, leaves, blossoms, fruits or seeds (Peiffer & Felton, 2014). Typically they use a 'lacerate and flush' feeding mechanism which involves repeated insertion and withdrawal of the stylet into the plant. The damaged cells are liquefied, and saliva is then used to flush the ruptured cell contents into the sucking mouthpiece for ingestion. They may also feed on leaf vascular tissue, which causes minimal mechanical damage. During feeding, the bugs may inject toxic saliva into plant tissues that causes further tissue damage, discoloration or may even make fruiting structures abort. Feeding damage can result in the abnormal production of new leaflets and pods, culminating in a 'green bean effect' (Ni *et al.*, 2010; Corrêa-Ferreira & De Azevedo, 2002; Silva *et al.*, 2012).

In the case of *H. halys*, once toxic saliva has been injected into fruits and seeds, damage can vary depending on the type, variety and maturity of the affected commodity (Bortolotti *et al.*, 2015).

Histologically, the most common effect of feeding by *H. halys* on almost mature fruit is the development of a 'salivary cone', a hardening of the tissue (similar to a lump) at the point of puncture, whereas fruit deformation is due to the injection of toxic saliva into an immature fruit. The latter often results in depreciation or complete loss of commercial value of the affected commodity (Bortolotti *et al.*, 2015).

Brown marmorated stink bugs can induce two main types of damage in grapes: (a) reduction in fruit weight (it has been estimated that five adult bugs can reduce the weight of a bunch of grapes by up to 37%), with visible cracks in the berries (Mohekar, 2016); and (b) during wine making its presence on grapes will result in the release of tridecane and trans-2-decenal (its defence chemicals) due to insect distress during in the fruit crush; these chemicals may remain present in the wine at the end of the fermentation process, thus affecting quality (Mohekar, 2016).

Halyomorpha halys is also known to transmit damaging phytoplasma diseases to ornamental tree and shrubs (Jones & Lambdin, 2009). Paulownia witches' broom is one of the most important diseases transmitted by this bug, affecting more than 880 000 ha of *Paulownia tomentosa* trees intended for timber production in China and causing losses amounting to billions of dollars (Hiruki, 1997).

Distribution

During summer, adult *H. halys* are frequently capable of long-distance flights of up to 100 km (Wiman *et al.*, 2015), which may be why this bug has managed to spread so rapidly in North America and Europe. It can certainly be transported over large distances via automotive and air transportation (Kriticos *et al.*, 2017), sea freight (Duthie, 2012) and through commerce in agricultural commodities.

Fig. 1 An adult *Halyomorpha halys*. [Colour figure can be viewed at wileyonlinelibrary.com]

The occurrence of *H. halys* outside its native range (Fig. 2) was first reported in the mid-1990s in Allentown, Pennsylvania (USA) (Hoebeke & Carter, 2003), from where it rapidly spread; it is currently present in 44 US states and in 4 provinces in Canada (National Institute of Food and Agriculture, 2018).

In Europe, *H. halys* was first observed in Switzerland in 2007 (Wermelinger *et al.*, 2008); since then it has been reported from Liechtenstein, Germany, Spain, France, Austria, Russia, Hungary, Bulgaria, Romania, Serbia and Greece (Costi *et al.*, 2017; Heckmann, 2012; Vétek *et al.*, 2014; Macavei *et al.*, 2015; Dioli *et al.*, 2016; Simov, 2016). In Italy, the species was first detected in 2012 as a single specimen collected near Modena in Emilia Romagna (Maistrello *et al.*, 2016). Within less than 4 years, *H. halys* had been found in all regions of Northern Italy, with frequent records in Central Italy and sporadic finds in the South (Bariselli *et al.*, 2016) including Sardinia and Sicily (Dioli *et al.*, 2016).

Bioclimatic models suggest that *H. halys* will be able to continue to expand from its current geographical range into the Southern Hemisphere, where regions with moist tropical, subtropical, Mediterranean and warm-temperate climates appear to be at substantial risk from this bug (Kriticos *et al.*, 2017) (Fig. 3).

The presence of *H. halys* in Malta

In recent years, the distribution range of *H. halys* has extended into the southern regions of the Mediterranean Basin. The Maltese Islands are situated in the centre of the Mediterranean Basin, so the presence of this stink bug in Malta could provide the portal for its introduction into North Africa. A survey therefore was carried out in

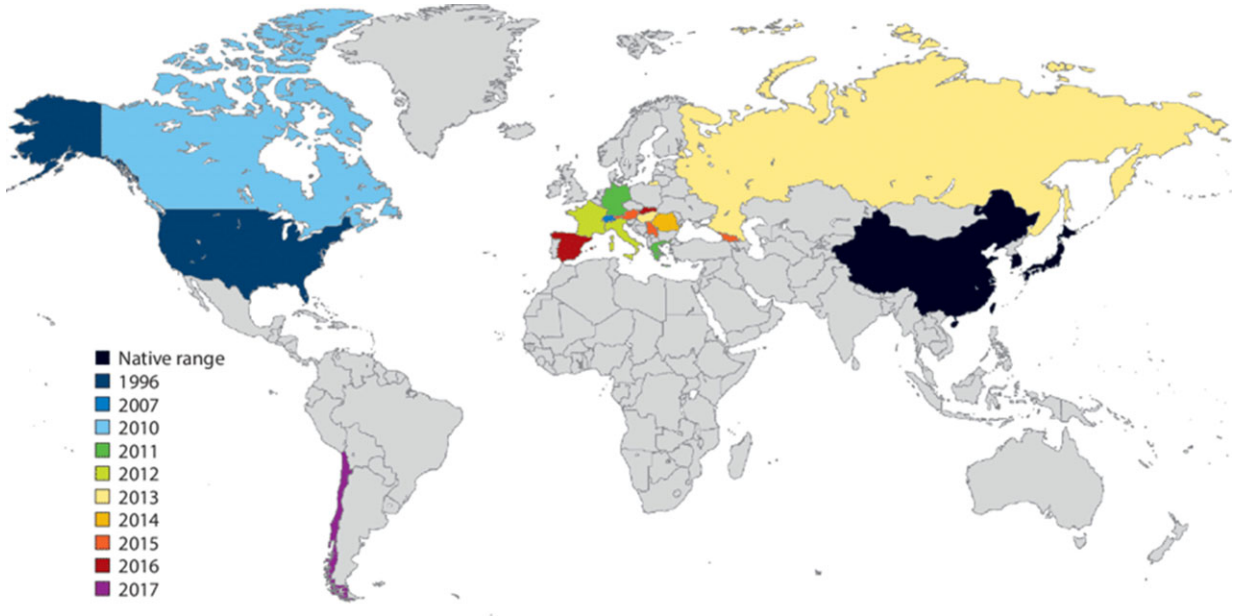

Fig. 2 Global distribution of established *Halyomorpha halys* populations in its native range and in the invaded regions (by year of detection, not of interceptions). Year of detection is based on published reports or data provided by the European and Mediterranean Plant Protection Organization (https://gd.eppo.int/taxon/halyha/distribution). [Colour figure can be viewed at wileyonlinelibrary.com]

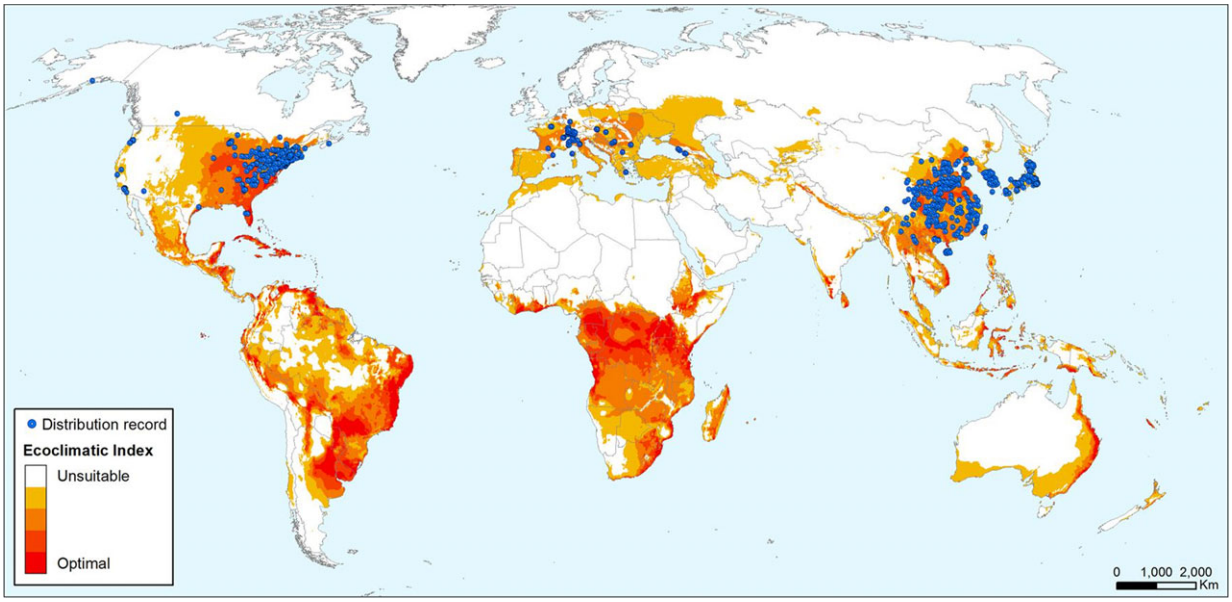

Fig. 3 Globally modelled climate suitability (CLIMEX Ecoclimatic Index) for *Halyomorpha halys*, including reported distribution locations (after Kriticos *et al.*, 2017). [Colour figure can be viewed at wileyonlinelibrary.com]

Fig. 4 Selected locations where sticky traps with aggregation pheromone were placed. [Colour figure can be viewed at wileyonlinelibrary.com]

the Maltese Islands to assess the possible presence of this species.

Methods

For the survey, 10 sampling localities were selected, 9 on Malta and 1 on the island of Gozo (Fig. 4). Localities were selected on the basis that either (a) they represented a homogenous coverage of Malta or (b) they represented points of entry of commercial commodities from all over Europe and from Third World countries or (c) they represented agricultural areas where host plants of this stink bug are available.

In each location, sticky traps with pheromone aggregation (produced by Trécé Incorporated) were used. The study

was carried out from 15 March 2018 to 31 May 2018. During this time, the traps were checked every 15 days for the possible presence of *H. halys*. Renewal of aggregation pheromone took place on 30 April. Sticky traps were only replaced when a large number of insects were attached. Table 1 provides the coordinates of each of the sample locations and information on habitat type.

Results and discussion

In the survey carried out in the Maltese Islands, one male *H. halys* was found near Freeport in Birżebbuġa on 15 May 2018. This location is one where many commodities are imported from Third World countries and a lot of transhipments take place between European Union countries; it represents a perfect location where alien introductions can take place. The surroundings of Freeport in Birżebbuġa are all agricultural fields where the trap was located. The discovery of this single male in Malta is significant. The specimen was intact and not damaged, indicating that this was most likely bred in Malta and that a small stable population already exists. Many alien invasive species are often captured as single individuals initially. During this time, they are interacting with the new environment. After some latent time (which is very variable) the alien species can easily become invasive. The risks associated with alien invasive pests (e.g. of widespread establishment or ecological impact) are difficult to quantify as they involve interactions between factors that operate across a range of spatial and temporal scales, such as the population dynamics of the invader, environmental conditions in the invaded region and the status of potential dispersal pathways (Barney & Whitlow, 2008). More time is required to better understand how this species will behave in southern Europe (e.g. in Sicily and Malta). Certainly, more surveys will be needed to try to understand the population dynamics of the pest locally.

Table 1. Data on each location where sticky traps and pheromones were placed

Location	Coordinates	Placement of traps	Date installed	Dates inspected
Gozo (Marsalforn Valley, agricultural land)	36°03′03.1″ N, 14°15′03.5″ E	Olive tree near vineyard	16 March 2018	29 March; 16, 30 April; 15, 31 May 2018
Simar (nature reserve)	35°56′41.8″ N, 14°23′02.1″ E	Grove	16 March 2018	29 March; 16, 30 April; 15, 31 May 2018
Rabat (agricultural land)	35°52′06.3″ N, 14°24′48.9″ E	Hazelnut near apricot trees	15 March 2018	29 March; 16, 30 April; 15, 30 May 2018
Tà Qali (natural park)	35°53′41.0″ N, 14°25′22.0″E	Grove near vineyard	15 March 2018	28 March; 16, 30 April; 15, 30 May2018
Msida (university grounds)	35°54′15.0″ N, 14°28′59.0″ E	Grove	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018
Marsa (Addolorata cemetery)	35°52′17.0″ N, 14°29′59.0″ E	*Ficus carica*	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018
Siggiewi (agricultural land)	35°50′34.0″ N, 14°26′00.0″ E	Pear trees	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018
Luqa (airport)	35°51′03.0″ N, 14°29′33.0″ E	*Ficus atrocarpae*	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018
Zejtun (agricultural land)	35°50′44.9″ N, 14°33′04.5″ E	Shrubs	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018
Birżebbuġa (Freeport)	35°48′56.0″ N, 14°31′54.0″ E	Apricot tree	15 March 2018	28 March; 16, 30 April; 15, 30 May 2018

La punaise diabolique *Halyomorpha halys* (Hemiptera : Heteroptera : Pentatomidae) signalée à Malte

Halyomorpha halys, communément nommée punaise diabolique ou punaise marbrée, est signalée pour la première fois à Malte. Ce signalement est actuellement basé sur la capture d'un unique spécimen. Des informations sont fournies sur l'aire de répartition de cette espèce polyphage qui a été accidentellement introduite en Europe (Suisse) en 2007 et a dès lors envahi de nombreux pays européens. Des détails morphologiques sont également inclus afin d'aider à la distinguer d'espèces similaires présentes dans la région méditerranéenne. Des notes sont fournies sur la stratégie d'alimentation de cet insecte et le type de dommages causés sur les marchandises agricoles qui en deviennent souvent impropres à la commercialisation.

Коричнево-мраморный клоп *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae) на Мальте

Присутствие *Halyomorpha halys*, широко известного, как коричнево-мраморный клоп был впервые зафиксирован на Мальтийских островах. В настоящее время данные основываются на поимке одной особи. В статье представлена информация об области распространения этого многоядного вида, который был случайно интродуцирован в Европу (в Швейцарию) в 2007 году и с тех пор распространился во многие европейские страны. Также включены морфологические детали для помощи в отличии этого вида от сходных видов, встречающихся в Средиземноморском регионе. Приводится информация о стратегии питания этого насекомого, а также о типе ущерба, наносимого сельскохозяйственным товарам, которые часто становятся непродаваемыми.

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